COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINERAL RESOURCES

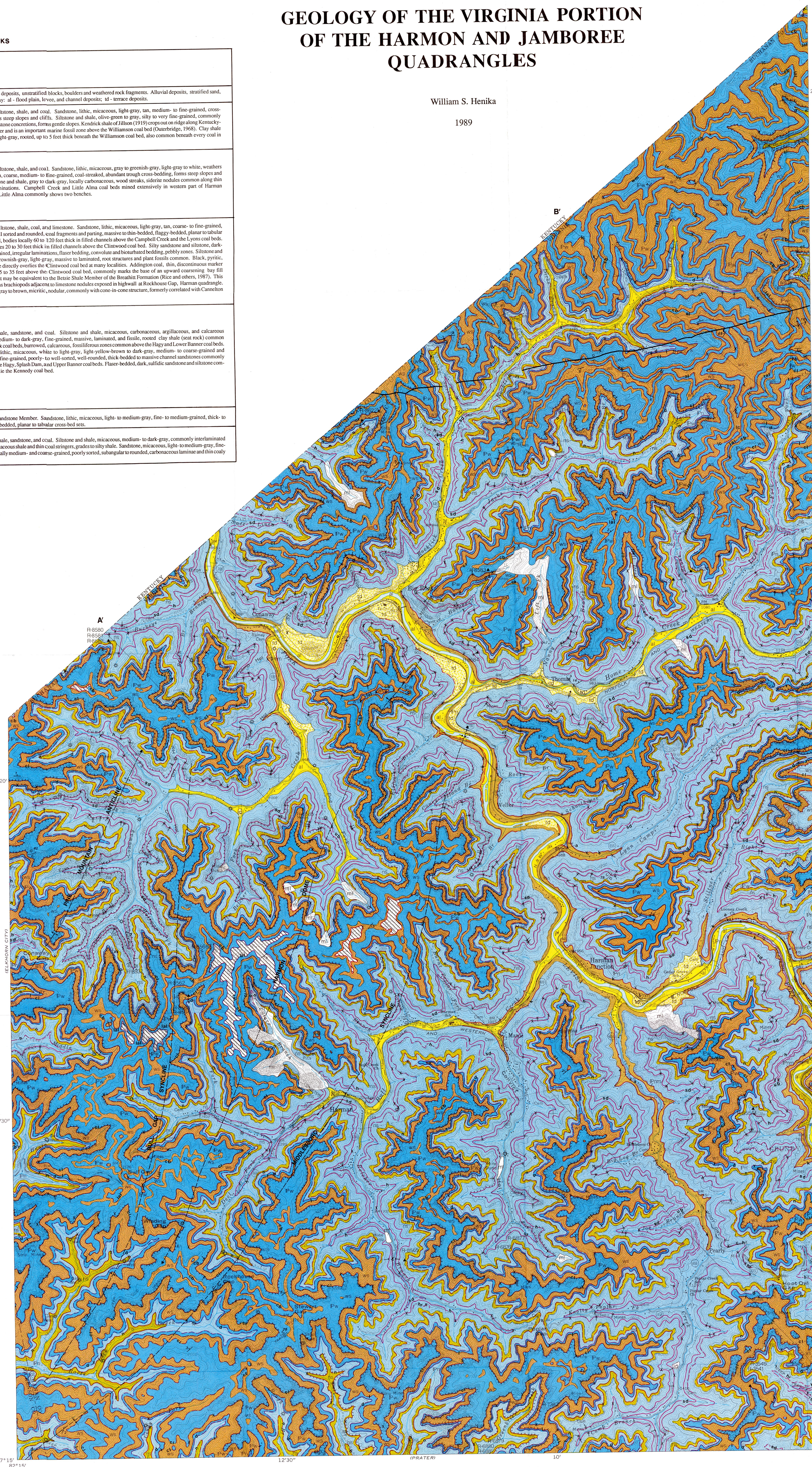
GEOLOGY OF THE VIRGINIA PORTION OF THE HARMON AND JAMBOREE QUADRANGLES

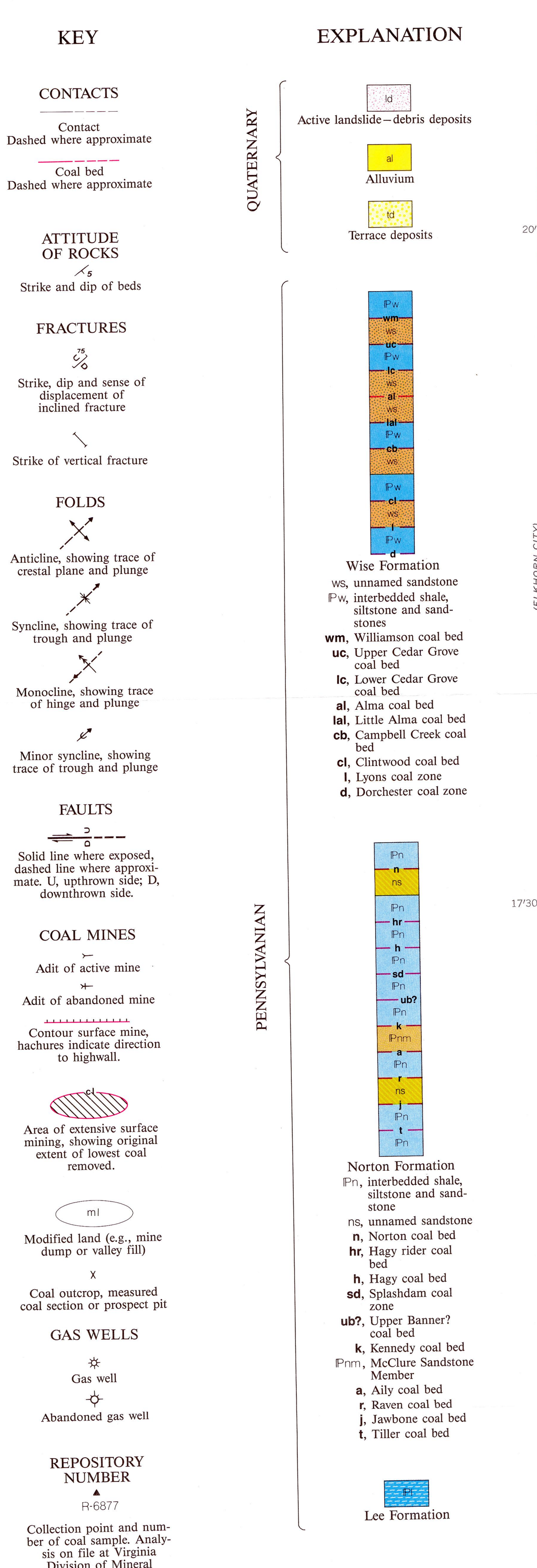
William S. Henika

1989

COLUMNAR SECTION OF SURFACE ROCKS

SYSTEM AND SERIES	FORMATION, MEMBER, AND BED	LITHOLOGY	COAL THICKNESS IN INCHES	UNIT THICKNESS IN FEET		
QUATERNARY	ALLUVIAL AND LANDSLIDE DEPOSITS			0–40		ld, Land-slide deposits, unstratified blocks, boulders and weathered rock fragments. Alluvial deposits, stratified sand, gravel and clay: al - flood plain, levee, and channel deposits; td - terrace deposits.
PENNSYLVANIAN, LOWER AND MIDDLE, WISE FORMATION				250–150	250–200	Sandstone, siltstone, shale, and coal. Sandstone, lithic, micaceous, light-gray, tan, medium- to fine-grained, cross-bedded, forms steep slopes and cliffs. Siltstone and shale, olive-green to gray, silty to very fine-grained, commonly includes limestone concretions, forms gentle slopes. Kendrick shale of Jillson (1919) crops out on ridge along Kentucky-Virginia border and is an important marine fossil zone above the Williamson coal bed (Outerbridge, 1968). Clay shale (seat rock), light-gray, rooted, up to 5 feet thick beneath the Williamson coal bed, also common beneath every coal in column.
	Kendrick Shale of Jillson (1919)			30–90		
	Williamson coal bed		1.5–2.0	140–80	620–430	Sandstone, siltstone, shale, and coal. Sandstone, lithic, micaceous, gray to greenish-gray, light-gray to white, weathers buff to brown, coarse, medium- to fine-grained, coal-streaked, abundant trough cross-bedding, forms steep slopes and cliffs. Siltstone and shale, gray to dark-gray, locally carbonaceous, wood streaks, siderite nodules common along thin beds and laminations. Campbell Creek and Little Alma coal beds mined extensively in western part of Harman quadrangle, Little Alma commonly shows two benches.
	Upper Cedar Grove coal bed		0–1.4	200–130		
	Lower Cedar Grove coal bed		0–2.2 0–1.0	150–100		
	Alma coal bed		0–1.0	40–50		
	Little Alma coal bed		0.7–3.4	40–80		
	Campbell Creek coal bed		1.0–5.5	100–35	400–280	Sandstone, siltstone, shale, coal, and limestone. Sandstone, lithic, micaceous, light-gray, tan, coarse- to fine-grained, pebbly to well sorted and rounded, coal fragments and parting, massive to thin-bedded, flaggy-bedded, planar to tabular cross-bedded, bodies locally 60 to 120 feet thick in filled channels above the Campbell Creek and the Lyons coal beds. Smaller bodies 20 to 30 feet thick in filled channels above the Clintwood coal bed. Silty sandstone and siltstone, dark-gray, fine-grained, irregular laminations, flaser bedding, convolute and bioturbated bedding, pebbly zones. Siltstone and clay shale, brownish-gray, light-gray, massive to laminated, root structures and plant fossils common. Black, pyritic, nodular shale directly overlies the Clintwood coal bed at many localities. Addington coal, thin, discontinuous marker coal about 15 to 35 feet above the Clintwood coal bed, commonly marks the base of an upward coarsening bay fill sequence that may be equivalent to the Betsie Shale Member of the Breathitt Formation (Rice and others, 1987). This shale contains brachiopods adjacent to limestone nodules exposed in highwall at Rockhouse Gap, Harman quadrangle. Limestone, gray to brown, micritic, nodular, commonly with cone-in-cone structure, formerly correlated with Cannelton Limestone.
	Betsie Shale of Rice and others (1987)			150–80		
	Addington coal bed		0–0.5			
	Clintwood coal bed		1.0–6.0	120–45		
	Lyons coal zone		0–9.6	20–50		
	Dorchester coal zone		0–6.4	◄ 40–100		
PENNSYLVANIAN, LOWER AND MIDDLE, NORTON FORMATION	Norton coal zone		0.4–6.2	200–150	700–650	Siltstone, shale, sandstone, and coal. Siltstone and shale, micaceous, carbonaceous, argillaceous, and calcareous varieties, medium- to dark-gray, fine-grained, massive, laminated, and fissile, rooted clay shale (seat rock) common beneath thick coal beds, burrowed, calcareous, fossiliferous zones common above the Hagy and Lower Banner coal beds. Sandstone, lithic, micaceous, white to light-gray, light-yellow-brown to dark-gray, medium- to coarse-grained and medium- to fine-grained, poorly- to well-sorted, well-rounded, thick-bedded to massive channel sandstones commonly cut across the Hagy, Splash Dam, and Upper Banner coal beds. Flaser-bedded, dark, sulfidic sandstone and siltstone commonly overlie the Kennedy coal bed.
	Eagle Limestone of White (1891)					
	Hagy rider coal bed Hagy coal bed		0–4.7	140–50		
	Splash Dam coal zone		1.3–7.2	40–70		
	Upper Banner coal bed		0–1.5	150–100		
	Lower Banner coal bed		0–0.5	215–130		
	Kennedy coal bed		1.0–2.2			
LWR.	McClure Sandstone			110–70	220–180	McClure Sandstone Member. Sandstone, lithic, micaceous, light- to medium-gray, fine- to medium-grained, thick- to very-thick-bedded, planar to tabular cross-bed sets.
	Aily coal bed		0–1.6	50–60		Siltstone, shale, sandstone, and coal. Siltstone and shale, micaceous, medium- to dark-gray, commonly interlaminated with carbonaceous shale and thin coal stringers, grades to silty shale. Sandstone, micaceous, light- to medium-gray, fine-grained, locally medium- and coarse-grained, poorly sorted, subangular to rounded, carbonaceous laminae and thin coaly partings.
	Raven coal bed		0–1.2	30–40		





Base map from U.S. Geological Survey, 7.5-minute series Harmom, 1963, PR 1977; Jamboree, 1963, PR 1977. Project funded equally by the Commonwealth of Virginia and the U.S. Department of Interior, Office of Surface Mining, under a Technical Data Management System grant.

UTM GRID AND 1977 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

QUADRANGLE LOCATION

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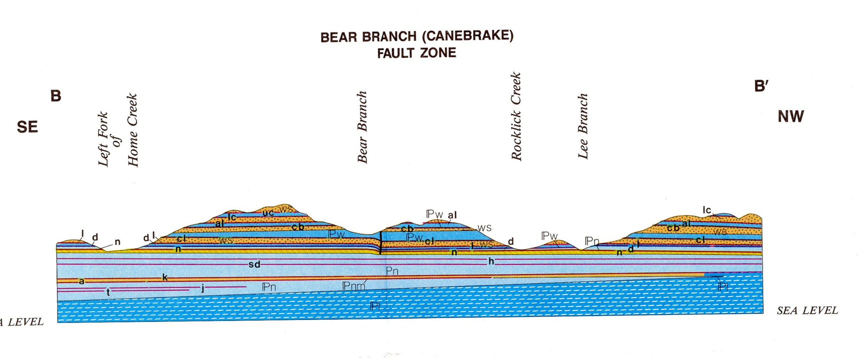
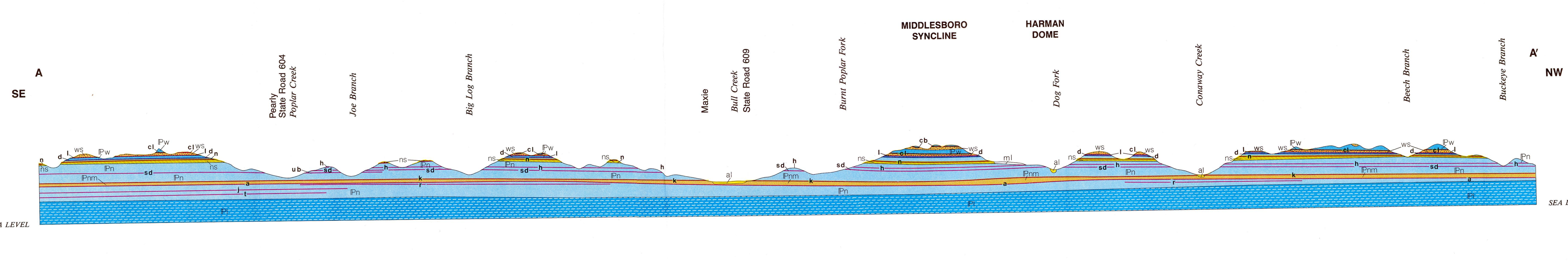
COLUMNAR SECTION OF SUBSURFACE ROCKS

SYSTEM AND SERIES		FORMATION	MEMBER AND BED	LITHOLOGY	UNIT THICKNESS	DRILLERS TERM
PENNSYLVANIAN	LOWER	Norton Formation	Jawbone coal Tiller coal			
		Lee Formation	Middlesboro Member		580–1280	Salt Sands
		Pocahontas Formation			0–100	
MISSISSIPPIAN		Bluestone Formation			0–550	
		Hinton Formation	Tallery Sandstone Member		30–168	Ravencliff Sand
			Little Stone Gap Member		0–20	
			Middle Red member		280–650	
			Stony Gap Sandstone Member		0–150	"Maxton" or "Maxon" Sands
		Bluefield Formation			10–390	
		Greenbrier Limestone			270–460	Big Lime
		Maccrady Formation			50–100	Injun Sand
		Price Formation			190–260	Weir Sand
		Chattanooga Shale	Big Stone Gap Member		360–370	
			Bedford equivalent		15–70	"Berea Sand"

BEAR BRANCH (CANEBRAKE) FAULT ZONE



CROSS SECTION DESIGN
1. No vertical exaggeration.
2. Subsurface units interpreted from surface and drill-hole data.
3. Coal bed thickness is diagrammatic.
4. This surficial deposits not shown.



The Virginia portion of the Harman and the Jamboree quadrangles is located in the northwestern part of Buchanan County. The area constitutes approximately 68.5 square miles in the Appalachian Plateaus physiographic province and is underlain by gently arched sedimentary rocks of Lower and Middle Pennsylvanian age. The high plateau has been cut by the northwest trending canyon of the Levisa Fork which is the major stream valley in the area. Topographically the area is characterized by steeply sloping ridges and V-shaped valleys. The highest point is on a ridge along the Kentucky border which is marked 2479 feet in the area north of Wes Lee Fork of Rocklick Creek, Jamboree quadrangle. The lowest point is approximately 845 feet in the Levisa Fork Valley near the Kentucky border in Harman quadrangle.

Field investigations in the Virginia portion of the Harman and Jamboree quadrangles were begun in 1979 with the assistance of Peter S. Frischman and Thomas M. Gathright, II. Barry Miller, Jeremy Grantham, and Gerald Wilkes collected additional field data and valuable coal samples in the area during the 1982-83 field season. The field work was completed and maps were compiled by W. S. Henika in the 1988-89 field season. The Kentucky portion of the Harman and Jamboree quadrangles (Alvord and Miller, 1972; Outerbridge and Van Vloten, 1968) was published by the U.S. Geological Survey through a cooperative mapping program with the Kentucky Geological Survey.

STRATIGRAPHY

Approximately 1900 feet of Pennsylvanian-age sandstone, siltstone, shale, seat rock, and coal beds are exposed in the area (see columnar section of surface rocks). These units comprise two formations, the Norton Formation, which is exposed along the lower slopes and in the streams and the Wise Formation which occupies the higher hilltops. The boundary between the Norton and the Wise was previously placed at the top of what was thought to be the Gladeville Sandstone. The Gladeville, however, could not be traced from the southwest across the Haysi quadrangle into Buchanan County (Henika, 1989). Sandstones in the Lower Wise are indistinguishable from those in the Upper Norton in this area. Because the definitive quartzarenitic facies of the Gladeville is missing the sandstone bodies had to be traced carefully to maintain stratigraphic control. The lack of a consistent Gladeville Sandstone marker required that the base of the Wise Formation be placed at the base of the Dorchester coal zone in Harman and Jamboree quadrangles.

Two marine units were noted in the Norton Formation, one is between the Lower and Upper Banner coal beds and is 60 to 110 feet below the Splash Dam coal zone. The other correlates with the Eagle limestone of White (1891) and forms a persistent zone near the top of the Norton Formation and is between 70 and 150 feet below the Norton coal zone. Two marine units were also noted in the Wise Formation. The Betsie Shale Member of the Wise Formation (Rice and others, 1987), previously correlated with the Cannelton Limestone, was found throughout the area between the Clintwood and the Campbell Creek coal beds. It can be up to 150 feet thick and directly overlies the Clintwood coal bed in the western part of the area. In the Grundy quadrangle it lies above the Addington coal, about 15 to 35 feet above the Clintwood coal (Taylor, 1989). The Kendrick Shale Member of the Wise Formation is the uppermost of the four marine zones recognized in the Harman and Jamboree quadrangles. It directly overlies the Williamson coal along the Kentucky-Virginia boundary in high country northwest of Rocklick Creek in Jamboree quadrangle. The Kendrick appears to be at least 20 feet thick and the upward coarsening shale, siltstone, and flaggy-bedded sandstone interval may be up to 60 feet thick. These distinctive, upward coarsening, rock sequences have been described as bay fill deposits by Rice and others (1987).

The subsurface section of coal bearing Pennsylvanian-age sandstone, siltstone, and shale may be as thick as 1300 feet in the Harman and Jamboree quadrangles. The lowest units exposed in the Norton Formation may lie as much as 200 feet above the base of the unit. The contact between the Norton and the Lee Formations, as redefined by Miller (1974, p. 70-78), can be recognized in the subsurface on gamma-ray logs. The characteristic "blocky" gamma-ray log signature of the upper quartzarenite units in the Lee serves to distinguish them from the overlying Norton sandstones. The contact between the Lee and Norton was placed from less than 100 feet to more than 300 feet below the Kennedy coal bed using gamma-ray logs and formational top descriptions based on subsurface studies in the area (Miller, 1974, p. 135-208, Appendix). See cross section A-A'. The McClure Sandstone Member grades laterally into the upper quartzarenite member (Bee Rock Member; Eby, 1923) of the Lee Formation in the northwestern part of the area, see cross section B-B' (Miller, 1974, p. 76). Exposures of the McClure Sandstone along the Levisa Fork and on the lower part of Conaway Creek show planar to tabular cross-bedding forms similar to cross-bedding typical of the Lee but lacking the quartzarenitic composition of the Lee.

The basal Pennsylvanian-age unit is the Pocahontas Formation, a gray shale and sandstone unit beneath the lowest massive quartzarenite of the Lee and above red Mississippian-age shale and mudstone. Drill records (Miller, 1974, p. 140-172, Plate 1) indicate that the Pocahontas ranges in thickness from 0 to about 100 feet in this area. The Pocahontas is absent locally because of a pre-Lee erosion surface beneath the basal Lee conglomeratic sandstone unit.

STRUCTURAL GEOLOGY

The Pennsylvanian-age rocks in the Harman and Jamboree quadrangles are located near the northwestern end of the Cumberland overthrust block (McLoughlin, 1986). The Cumberland block has been folded into a series of northeast trending anticlines and synclines. The Pine Mountain anticline and the Middlesboro syncline, shown on Harman quadrangle, are the northeastern most structures recognized on the Cumberland block. The Middlesboro syncline is bifurcated by a seven-mile-long anticlinal arch near its northeastern end. This local structure was named the Harman dome for the town to the southeast of the structure. The synclinal trough was named the Bull Gap syncline for the steep mountain pass near the southwestern end of the fold.

The southwestern plunging nose of the dome separates the Bull Gap syncline from the main trough of the Middlesboro syncline. Miller (1974, p. 15) has drawn a strike slip fault more or less parallel to Jess Fork which may actually separate the Harman dome from the Pine Mountain anticlinal culmination. Detailed mapping indicates that there is no fault at the surface which separates the two anticlines. A structural contour map drawn on the Kennedy coal bed does show an overly steep plunge on the nose of the Pine Mountain anticline which could suggest the presence of a fault in the subsurface.

Rich (1934) recognized that the northeast trending folds on the Cumberland block were rootless structures developed above a major detachment zone. Harris and Milici (1977) elaborated on Rich's thin-skinned model by showing how the Pine Mountain anticline may have developed by subsurface duplication as older rocks moved up a tectonic ramp during northwestward thrusting along the Pine Mountain fault. Miller (1974, p. 15) postulated that the western part of the Harman quadrangle might be on another thrust sheet separated from the main Cumberland block by the Russell Fork cross fault. Analysis of the major folds in the area indicate that the continuation of the Pine Mountain overthrust northeast of the Russell Fork fault is a likely explanation for the persistence of the fold geometry noted by Harris and Milici (1977) to the northeast of the Russell Fork fault. A simple computation based on conservation of rock volume indicates that the depth to the detachment beneath the folds in cross section A-A' is about 900 to 1000 feet beneath the Splash Dam coal bed. The anomalously thick Lee middle quartzarenite unit recognized by Miller (1974) within the Harmon dome may be the result of tectonic duplication along a detachment zone localized in a prominent shale horizon, which can be recognized in the gamma-ray logs from nearby gas wells that penetrate the unit.

The northeastward termination of the major folds of the Cumberland block occurs along a northwest trending structural trough that appears to have localized the development of the narrow entrenched meander belt of Levisa Fork between the town of Grundy and the Virginia-Kentucky border. This prominent cross structure, which is well defined on structural contour maps drawn on the Splash Dam and Hagy coal beds, may be a transverse tectonic ramp where a detachment fault beneath the folds to the southwest steps up to higher levels toward the northeast.

A persistent, linear zone of deformed bedding in rocks above the Dorchester coal was traced across the southeastern part of the Jamboree quadrangle. The zone, herein named the Bear Branch fault zone, was not found to cut rocks beneath the Dorchester coal zone. The deformation follows a straight line trending N 75°E across the map of the Becky Mining Company's No. 2 mine near the head of Rocklick Creek, and is expressed as linear roof- fall areas above the Lyons coal bed in that mine. Bedding rolls oriented from 0 to 75° azimuth were noted in surface outcrops both to the northeast and the southwest of the mine. Bedding contours on the mine roof indicate less than 10 feet of vertical displacement across the zone. Fold axes orientations obtained from field measurements and coal bed contours suggest oblique convergence (transpression) across the zone. The fault zone appears to be aligned along the westward projection of the Bishop-Bradshaw Creek fault lineament and is subparallel to but northeast of a lineament spur projecting from the Bishop-Bradshaw Creek lineament noted by McLoughlin (1986).

ECONOMIC GEOLOGY

COAL

The Division of Mineral Resources (DMR) is standardizing the names of coal beds in southwestern Virginia, using the coal bed names described in the Wise County area. Where correlation is uncertain the names have been retained that were used by early workers, in the northwestern part of Buchanan County and the southeastern part of Pike County, Kentucky, such as Hinds (1918), Outerbridge and Van Vloten (1968) and Alvord and Miller (1972). Where coal beds have been described using local names in the past, the locally used name will be shown in parentheses after the name presently used by DMR.

There are at least nine mineable coal beds in the Wise and the Norton Formations that occur above drainage in this area. Coal analyses values, on an as received basis, for 22 samples from six different coal beds indicates the mines in the area are generally producing a high rank of high-volatile A bituminous coal. It is washed and blended at several large preparation plants along U.S. Highway 460 and State Roads 650 and 609. Test results are tabulated in the Table. Both surface and underground mining techniques are used in the area. Mining is currently limited to the Little Alma (Pond Creek rider), the Campbell Creek (Imboden, Pond Creek), the Clintwood (Matewan), the Lyons (Eagle, Little Eagle), the Dorchester (Blair, Glamorgan), the Norton (Glamorgan, Hagy), the Hagy, and the Splash Dam (Upper Banner) coal beds. In the past some coal may have been mined from the Kennedy coal bed as well.

Deep gas tests (Miller, 1974, p. 35-93) and coal exploration borings indicate that there may be thin coal beds in the Pocahontas and the Lee Formation from about 500 to 1000 feet below drainage in this area. Miller indicates, however, that none of these coals is likely to be economically attractive because of stratigraphic thinning and great depth.

Only two coal beds in the subsurface portion of the Norton Formation can be considered important markers; they are shown on cross sections A-A' and B-B'. These coal beds, the Jawbone and Tiller beds, are mined to the southeast of the area where they are much thicker (Taylor, 1989). They are considered too thin by Miller (1974, p. 84-89) to be mineable in the northwestern part of Buchanan County.

The Raven coal bed is the lowest coal bed exposed at or above river level along Levisa Fork near the eastern boundary of the Harmon quadrangle. It was 1.2 feet thick near the mouth of Poplar Creek and thins to less than one foot towards the northwest. It crops out at elevations between 960 and 1060 feet and is about 100 feet above the top of the Lee Formation in the northwestern part of the area and up to 500 feet above the Lee in the southeast part of the area (cross section A-A'). Taylor (1989) reported several coal beds in this 500-foot interval below the Raven in the Grundy quadrangle to the east.

The Aily (Raven No. 3) coal bed occurs about 60 to 90 feet above the Raven coal bed along Levisa Fork in the eastern part of the area. The bed was measured at seven localities along Levisa Fork and at two localities along Poplar Creek and is 1.5 feet thick on the average. The Aily dips about 90 feet per mile toward the northwest to a point near the mouth of Mikes Branch. The Aily coal bed is generally just below the McClure Sandstone Member of the Norton Formation. This massive-bedded, coarse-grained sandstone is a prominent cliff maker from the Kentucky border southeast along the Levisa Fork to Grundy. It is from 70 to 150 feet thick in this area.

The Kennedy coal bed generally is 5 to 15 feet above the McClure Sandstone and is a prominent structural marker across the whole area. Along Levisa Fork the Kennedy has a regional dip of between 50 and 80 feet per mile to the northwest. A tabulation of twenty coal sections measured on Kennedy outcrops averages 1.6 feet. The coal ranges from between 1.0 foot and 2.9 feet with thicker sections commonly showing thin shale partings. The Kennedy was mined locally near the mouth of Poplar Creek (Hinds, 1918, p. 102) where the coal was 2.8 feet thick with a 0.2-foot-thick shale parting 0.1 foot from the top.

Boreholes along U.S. Highway 460 from Harman Junction to the Virginia-Kentucky border indicate that no coal beds of mineable thickness occur in the 270- to 350-foot zone between the Kennedy and Splash Dam coal beds. A 0.5 foot thick coal noted in the highwall at the Wellmore Coal Company loading dock along Levisa Fork below Poplar Creek was correlated with the Lower Banner coal bed and is approximately 110 feet below the Splash Dam interval at this locality. Hinds (1918, p. 109) described thin blooms of both the Lower and the Upper Banner coal beds in the area, and noted an Upper Banner outcrop 1.4 feet thick about 40 feet below the Splash Dam coal on Duty Branch of Poplar Creek. Thin coal beds were noted in this interval in several drill holes and at an active Splash Dam mine in the southeastern corner of the Harman quadrangle by Taylor (1989).

The Splash Dam coal zone consists of one to three separate coal beds interbedded with sandstone, shale, or siltstone. The zone is commonly above a massive 60-feet-thick ledge of sandstone. The coal zone is about 250 feet above the Kennedy coal bed in the northwestern part of the area; this interval increases to 350 feet towards the southeastern part of the area (cross section A-A'). Following a similar stratigraphic trend, the coal zone thickens from about 15 feet at the northwestern margin of the area to nearly 50 feet in the Grundy area. The Splash Dam coal bed is thickest where the two main benches in the zone nearly come together in the central part of the area. The thickest interval was 8.9 feet measured at the Harman No. 3 mine on Belcher Branch about one mile west of Poplar Gap (R-8565). There commonly is a rooted siltstone parting about 2 feet thick between the upper and the lower coal beds. The upper bed mined at this locality was 4.1 feet thick inside the mine where it was sampled in 1982 (G. P. Wilkes, personal communication 1989). Most of the thicker Splash Dam coal has been removed in the southeastern part of Harman quadrangle. Mines are still active in the northwestern part of the area on Beach Branch of Buckeye Creek, along Belcher Branch in the west-central part of Harman quadrangle, and southeast of Hoot Owl Gap in the southeastern corner. One-hundred measured coal sections in the area yields an average Splash Dam coal bed thickness of 4.6 feet.

The Hagy coal is generally 80 to 110 feet above the Splash Dam bed. Like the Splash Dam there are multiple coal beds above a ledge-making sandstone within the Hagy interval. A northwestward trending area of thick coal appears to parallel a pronounced northwest trending structural trough which is also coincident with the Valley of Levisa Fork. Within one mile of the Levisa Fork Valley there are eight measured sections of Hagy coal that range from 3.9 to 4.3 feet in thickness, whereas the average of eighty-six coal sections measured across the Harman quadrangle is only 3.0 feet. Most of the thick Hagy coal bed along the Levisa Fork has been mined and the mines currently working are mining 3 to 3.5 feet of coal with a few partings.

The Norton (Glamorgan, Blair) coal zone consists of an interval of interbedded siltstone, sandstone, shale, and coal beds 20 to 30 feet thick. There are generally two prominent beds of coal in the zone which may be separated by 5 to 25 feet of shale, siltstone, or sandstone. The coal bed at the base of the Norton coal zone is 50 to 100 feet below the top of the Norton Formation and overlies a 30- to 60-feet-thick, cliff-forming sandstone. It is from 150 to 200 feet above the Hagy coal bed. The lower Norton coal bed is usually the thicker, more persistent one in the zone. The Norton coal exposures are poor and generally inaccessible, lying high on steep mountain slopes to the northeast and southwest of the Levisa Fork Valley.

The Norton coal was mined from a thick zone along the Levisa Fork structural trough axis near Harman Junction where two coal beds, separated by up to 3 feet of shale, formed an eigh-feet-thick bench. The coal in the Norton coal zone was strip mined along Dog Fork in the northern part of Harman quadrangle, along Greenbrier Creek and Deel Branch in the southern part of Harman quadrangle, and at the head of Left Fork in the southeastern corner of the Jamboree quadrangle. Most of the thicker beds of Norton coal appear to have been mined in the Harman and Jamboree quadrangles. Forty-five coal sections measured in the area averaged only 2.1 feet and commonly had additional thick shale partings.

The Dorchester (Blair, Little Eagle) coal zone is from 10 to 25 feet thick and contains one to three beds of coal interbedded with shale, siltstone, or sandstone. The zone is 20 to 50 feet above the highest coal in the Norton coal zone and lies 20 to 50 feet beneath the lowest coal bed in the Lyons coal zone. The Dorchester is separated from the Norton coal zone by a massive sandstone at some localities, but there is no consistent marker separating the Wise and Norton Formations in this area.

The individual coal beds in the Dorchester coal zone have proven to be discontinuous and to thin radically across a specific mine site. There is a large, well-defined area of thick coal mapped as the Dorchester zone in the southeastern corner of the Harman quadrangle, centered on the Poplar Creek drainage basin. Sixteen coal-bed measurements in this area averaged nearly 6 feet in thickness, whereas the average for the whole area is only 3.8 feet for fifty measurements. The area of thicker coal may be partly concordant with the aforementioned Levisa Fork structural trough. This area also appears to be coincident with the coalescing of the multiple coal beds of the Dorchester coal zone.

The Lyons (Eagle) coal zone consists of one to three coal beds interbedded within a 1 to 30-feet-thick zone of shale, siltstone, or sandstone. The base of the Lyons coal zone is 20 to 50 feet above the base of the Wise Formation and the Lyons coals have proven to be more continuous and have a wider distribution than coals in the underlying Dorchester zone. The top of the Lyons coal zone is the base of a 45- to 150-feet-thick sandstone interval. This sandstone appears to truncate coal beds in the Lyons zone at some localities and is one of the most prominent stratigraphic marker beds in the region.

Coal beds in the Lyons coal zone averaged 3.6 feet in thickness at ninety widely spaced sections measured in the Harman and Jamboree quadrangles. Thick sections of Lyons coal that are now largely mined, were concentrated in three areas in the Harman quadrangle. The thickest sections were measured in the Big Rock area near the north end of the Harman quadrangle where seven sections averaged 5.6 feet of coal with up to 1.6 feet of interbedded shale. This thick area approximately coincides with a regional structural saddle at the northeast end of the Harman dome. Another thick area of the coal, with an average of 4.3 feet, appears to be localized between the northeast end of the Pine Mountain anticlinal axis and the Harman dome axis. The third thick area is along Greenbrier Creek in the southern portion of the Harman quadrangle where ten sections measured at sites along the Lyons mine bench had an average of 5.2 feet of coal interbedded with shale partings that comprised up to half the thickness of the coal bed.

The Clintwood coal bed is the most persistent and the most extensively surface mined coal bed in the Wise Formation. It is about 500 feet above the Splash Dam and overlies a massive, coarse-grained sandstone unit 45 to 150 feet in thickness. The Clintwood coal has few shale partings and in this area is consistently greater than 4 feet in thickness, averaging 4.6 feet in fifty-eight sections measured in the quadrangles. Because the Clintwood bed is high up on the mountain slopes there have been very few large underground mines developed there, but most of the area has been either strip mined or auger mined. Some of the older mine benches in the southwestern part of Harman quadrangle were being remined during the 1988 field season using thin-seam mining machines.

The Clintwood coal bed is locally overlain by channel-sandstone bodies that can be up to 20 feet thick and several hundred feet across, but is generally overlain by a gray, siltstone unit that grades upward into a dark-gray to black, marine-shale unit (Betsie Shale Member, Cannelton Shale Member of previous DMR reports) 15 to 35 feet above the coal bed. Exposures, in the southwestern part of the area and along the border of the southeastern part of Harman quadrangle, locally have a thin-marker coal at the base of a shale sequence which was mapped in the Haysi area as the Addington coal bed. This unit is not a traceable marker in the Harman and Jamboree quadrangles.

The Campbell Creek coal bed (Lower Elkhorn, Pond Creek) is 170 to 220 feet above the Clintwood coal bed and overlies a persistent cliff making sandstone unit 35 to 100 feet thick. This sandstone unit was deposited directly above the Betsie Shale Member and locally fills channels cut into the underlying marine sequence. The Campbell Creek has been mined at the surface along the high ridgeline west of Levisa Fork. There the Campbell Creek coal bed and the overlying Little Alma coal bed are interbedded with massive, ledge forming, sandstone bodies and the mines are more like stone quarries with fifty-feet-thick benches than like coal pits. Thirteen sections measured on mine benches in the Harman quadrangle and along roads and forest trails in the Jamboree quadrangle indicate the Campbell Creek coal bed ranges from 1.0 to 4.5 feet thick and averages about 3.1 feet for the area.

The Little Alma coal bed is 40 to 80 feet above the Campbell Creek coal bed. It forms the base of the Alma coal zone which consists of 40 to 60 feet of interbedded black and gray shale, coal, and sandstone. The Alma coal bed at the top of the zone is not a traceable coal bed but rather a zone of interbedded thin coal stringers and black shale. The Little Alma coal comprises two beds where it was mined in the Jamboree quadrangle along a narrow strip at the head of Rocklick Creek. Nine Little Alma coal sections were measured across the area. The coal had a range of 0.7 to 3.4 feet in thickness and was 1.6 feet thick on the average.

The Cedar Grove coal beds were measured in blooms along the logging road to the northwest of the gap at the head of Rocklick Creek in the Jamboree quadrangle. They are about 1.5 feet thick and have not been prospected. The Williamson coal bed was exposed in prospects on the ridge northwest of Wes Lee Fork of Rocklick Creek and had a range in thickness of 1.5 to more than 2.5 feet in thickness. There is a 90-feet-thick shale unit above the Williamson coal that contains marine fossils and has been correlated with the Kendrick Shale Member of Jillson (1919). This coal zone has been extensively mined in mountain top removal operations in the Kentucky portion of the Jamboree quadrangle.

NATURAL GAS

Natural gas production in the Harman area is from an extension of the Big Sandy field of eastern Kentucky. Drilling records indicate that at least sixty gas wells have been drilled in the Virginia portion of the Harman and Jamboree quadrangles since 1954. Of the sixty wells recorded, fifty-seven wells are currently listed as producing, whereas two were plugged and abandoned as dry holes and one was abandoned after mechanical failure. Production records indicate that some of the older gas wells in this area have been productive for thirty-five years.

The most productive reservoir in this area has been the "Berea" sand which is a 70-feet-thick siliceous zone at the base of the Mississippian-age Big Stone Gap Member of the Chattanooga Shale. Outcrop-derived gamma-ray logs and petrography of rock samples from the Mississippian-age to Devonian-age shale section exposed to the southwest of the Harman area, along the Alleghany structural front (Diffenbach and Henika, 1988), indicate that the "Berea" is very-fine grained and would be better described as a siliceous-siltstone unit. Gas production from the "Berea" is apparently dependent on fracture permeability and continuous recharge from the surrounding organic-shale units. At least twenty-five of the wells are producing from this zone at depths from approximately 3400 to 4600 feet in the Harman area.

In addition to the "Berea" other reservoirs for natural gas include the Greenbrier Limestone, the "Big Lime" (at least fourteen wells), the "Maxon" sand (at least four wells), the Devonian shale (at least two wells) and the "Ravencliff" sand (at least one well). All of these reservoirs have produced and have been mingled with gas from the "Berea" sand. All of the productive reservoirs were identified on outcrop using surface-derived, gamma-ray logs of measured stratigraphic sections (Diffenbach and Henika, 1988). Production from the "Big Lime" comes from thin (less that 10 feet thick) zones of 5 to 15 percent porosity in the Mississippian-age Greenbrier Limestone at depths of 3400 to 3900 feet. "Maxon" sand production is from relatively thin zones (less than 20 feet thick) of moderate- to low-porosity sandstone (5 to 10 percent) at depths of 2900 to 3060 feet. The "Maxon" sandstones are interbeds of the middle and lower part of the Mississippian-age Hinton Formation and include the Stony Gap Member at the base. The "Ravencliff" sand reservoir is equivalent to the Tallery Sandstone Member at the top of the Hinton Formation. Henika (1988) described outcrops along the structural front to the southwest of the Harman area. Production from the "Ravencliff" comes from fracture-treated zones in both the upper and lower quartzarenites of the Tallery at depths of approximately 2050 to 2225 feet.

Initial production rates for twenty wells that had data available ranged from 34 to 1104 Mcfg/d (thousand cubic feet of gas per day). All of the wells were stimulated by fracture, acid treatment, or both. Production after stimulation ranged from 231 to 5180 Mcfg/d and the average for the thirty-two wells with data listed was 1703 Mcfgd.

OTHER MINERAL RESOURCES

Shale and siltstone in the thick stratigraphic interval between the Lower Banner and Upper Banner coal beds may have potential for use in the manufacture of lightweight aggregate. Samples collected from this interval exposed along State Highway 83 about 2.8 miles south of the boundary between the Harman and the Prater quadrangles were cited for this use by Johnson and others (1966). Sandstone in the McClure member of the Norton Formation was quarried for local use as road metal at a long abandoned quarry site near the mouth of Lynn Camp Creek. Sandstone near the top of the Norton Formation and the base of the Wise Formation was quarried at an open-pit mine at the head of Elijah Branch, west of the town of Weller. This material was used as road metal for mine roads in the local area and has not been tested or approved for use as grade-A aggregate by the Virginia Department of Transportation.

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Table. Coal analyses.

Parameter	Range	Average
Volatile matter	25.7 - 33.7%	30.3%
Fixed carbon	58.5 - 66.0%	60.6%
Ash	2.0 - 13.8%	6.7%
Total Sulfur	0.6 - 4.0%	1.3%
Btu/lb.	12377 - 15534	14106